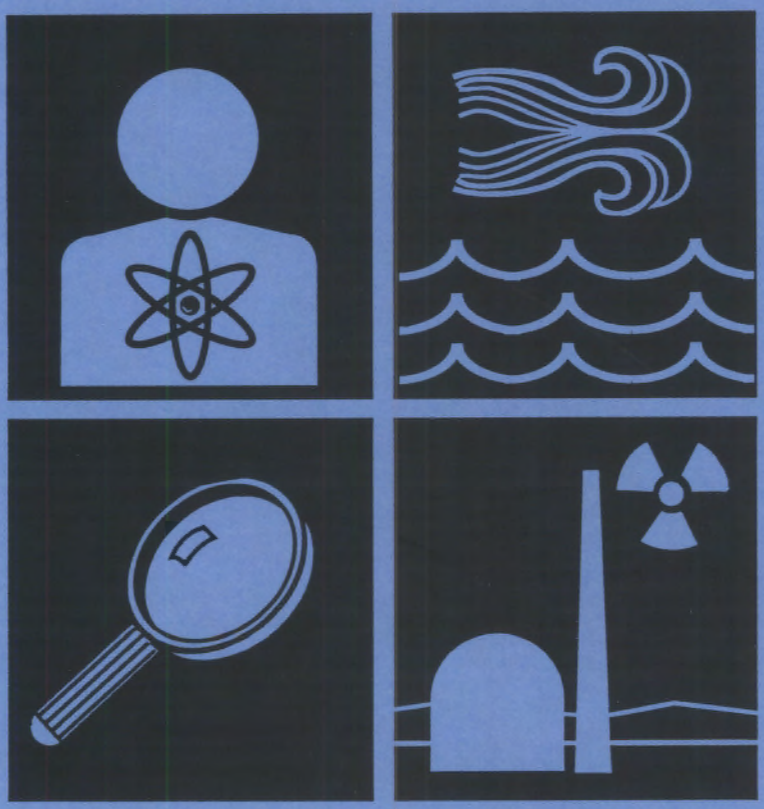
PNL-7248 HEDR
UC-707

6

Estimates of Columbia River Radionuclide Concentrations: Data for Phase I Dose Calculations

M. C. Richmond
W. H. Walters

May 1991



Prepared for the Technical Steering Panel

Battelle

PNL-7248 HEDR

DISCLAIMER

This report was prepared under the direction of the HANFORD ENVIRONMENTAL DOSE RECONSTRUCTION PROJECT Technical Steering Panel by Battelle Memorial Institute's Pacific Northwest Laboratories operating the Pacific Northwest Laboratory for the U.S. Department of Energy (DOE). While funding for the work was provided by DOE, the work is not under DOE direction or control. The views and opinions of the authors expressed in this document do not necessarily reflect those of the United States Government or any agency thereof. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer or otherwise does not necessarily constitute or imply its endorsement, recommendation or favoring by the U.S. Government or any agency thereof, nor by Battelle Memorial Institute.

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

PNL-7248 HEDR
UC-707

ESTIMATES OF COLUMBIA RIVER RADIONUCLIDE CONCENTRATIONS: DATA FOR PHASE I DOSE CALCULATIONS

Hanford Environmental Dose
Reconstruction Project

M. C. Richmond
W. H. Walters

May 1991

Prepared for
the Technical Steering Panel

Pacific Northwest Laboratory
Richland, Washington 99352

ESTIMATES OF COLUMBIA RIVER RADIONUCLIDE CONCENTRATIONS: DATA FOR PHASE I DOSE CALCULATIONS

May 1991

This document has been reviewed
and approved by the Technical Steering Panel.

John E. Till, Chairman
Technical Steering Panel
Hanford Environmental
Dose Reconstruction Project

April 29, 1991
Date

FOREWORD

Appendix C is a record of TSP comments and Battelle's responses to those comments; the TSP has reviewed and approved Battelle's responses. The comment numbers appear in this document in the left margin next to the paragraphs in which the corresponding comments are addressed. Any text that has been changed is shown in italics. In addition to changes to address TSP comments, some text has been changed for correction of errors and for further clarification.

SUMMARY

Pacific Northwest Laboratory is conducting the Hanford Environmental Dose Reconstruction Project to estimate the radiation doses people *may* have received from historical Hanford Site operations. Under the direction of an independent Technical Steering Panel, the project is being conducted in phases. The objective of the first phase is to assess the feasibility of the project-wide technical approach for acquiring data and developing models needed to calculate potential radiation doses.

This report summarizes data that were generated for the Phase I dose calculations. These included monthly average concentrations of specific radionuclides in Columbia River water and sediments between Priest Rapids Dam and McNary Dam for the years 1964 to 1966. Nine key radionuclides were selected for analysis based on estimation of their contribution to dose. Concentrations of these radionuclides in the river were estimated *using* existing measurements and hydraulic calculations based on the simplifying assumption that dilution and decay were the primary processes controlling the fate of radionuclides released to the river. Five sub-reaches between Priest Rapics Dam and McNary Dam, corresponding to population centers and tributary confluences, were identified and monthly average radionuclide concentrations were calculated for each sub-reach. The hydraulic calculations were performed to provide radionuclide concentration estimates for time periods and geographic locations where measured data were not available. The validity of the calculation method will be evaluated in Phase II.

CONTENTS

FIGURES

TABLES

INTRODUCTION

The Hanford Environmental Dose Reconstruction (HEDR) Project was established to estimate the radiation doses people *may* have received from operations that began at the Hanford Site in 1944. The project is being conducted by Battelle staff at the Pacific Northwest Laboratory (PNL) under the direction of an independent Technical Steering Panel (TSP). To comply with TSP directives, the HEDR Project is being conducted in phases. Results from each phase will be used to assist in defining the scope of work in the following phases.

14 The objectives of the first phase are to evaluate the feasibility of the project-wide technical approach for acquiring data and developing models needed to calculate potential radiation doses. For the dose calculations, monthly average concentrations of specific radionuclides in Columbia River water between Priest Rapids Dam and McNary Dam were estimated for the years 1964 through 1966. This location and time period were selected for Phase I study of the surface-water pathway because *this was a period of highest reactor operations, and thus, among the highest rates of discharge of radioactive material to the river.* In addition, the city of Richland, which is the nearest downstream population nearest to the Hanford Site, did not withdraw drinking water from the Columbia River until 1964.

This report presents the water and sediment concentration data generated by the surface-water transport subtask for use in Phase I dose calculations. Monthly average values of radionuclide concentrations in the river come primarily from Hanford environmental monitoring reports; where data are limited or not available, concentrations were determined from dilution and decay calculations.

The work described in this report was conducted in accordance with the requirements of ANSI/AMSE NQA-1 1986 Edition, Quality Assurance Program Requirements for Nuclear Facilities, as interpreted by PNL's Quality Assurance (QA) program. All procedures used to support this report were written

and controlled in accordance with PNL QA program requirements. Records that support the data in this report were created and stored in accordance with applicable HEDR Project record control procedures.

ESTIMATION OF PHASE I COLUMBIA RIVER CONCENTRATIONS

For Phase I, radionuclide concentrations in the Columbia River in both the water column and the sediments were estimated for the years 1964 to 1966 based on existing measurements and hydraulic calculations. The investigation of the Columbia River for Phase I is focused on that portion of the river between Priest Rapids Dam and McNary Dam to take advantage of the monitoring data that exist and data that were collected by the U.S. Geological Survey (USGS) for that reach of the river.

Monthly average radionuclide concentrations in the Columbia River for Phase I were estimated with measured data and hydraulic calculations based on dilution and decay of radionuclides in the river. A monthly time period was selected for averaging the concentrations because the dose calculations are being made on a monthly basis.

The radionuclides for which concentrations in the Columbia River were estimated are listed in Table 1. These key radionuclides were selected based on analysis of the source inventories and estimation of their contribution to dose (Napier 1989).

FIELD MEASUREMENTS OF RADIONUCLIDE CONCENTRATIONS

Concentrations of various radionuclides in river water at several locations were measured and reported by PNL staff (Wilson 1965; Moore and Essig 1966; Soldat and Essig 1966; Essig and Soldat 1967; and Essig 1967) and the USGS (Haushild et al. 1973). These measured data for total (dissolved

TABLE 1. Radionuclides of Interest for Surface-Water Transport *(Morgan 1980)*

Radionuclide	Half-Life (Days)
Arsenic-76	1.1
Chromium-51	27.8
Copper-64	0.53
Manganese-56	0.11
Neptunium-239	2.33
Phosphorous-32	14.3
Sodium-24	0.63
Zinc-65	245

and sediment-sorbed) radionuclide concentrations were reviewed and are listed in Appendix A (Tables A.1 through A.40) as "measured values." *Missing values indicate that no data were available.* These tables include the monthly average value of the weekly cumulative samples and the highest and lowest measurements for cumulative or grab samples. The high and low values illustrate the variability in the measured radionuclide concentrations. The tables also show the gaps in the existing measured data in terms of time, space, and the radionuclides of interest. These gaps made it necessary to estimate radionuclide concentrations in the river using hydraulic calculations for Phase I.

Limited data exist on radionuclide concentrations in Columbia River bed sediments; available data from Nelson (1965) and Haushild et al. (1975) are listed in Appendix B (Tables B.1 through B.4). Because sediment transport calculations were not performed, the values measured and reported in these references were applied to the entire 1964 to 1966 time period.

CALCULATION OF RADIONUCLIDE CONCENTRATIONS

13 As a first approximation, radionuclide concentrations in the Columbia River water column were calculated assuming that dilution and decay were the primary processes controlling the fate of radionuclides released to the river. *For monthly time periods, dilution and decay processes will account for the majority of the variability in Columbia River radionuclide concentrations.* Calculations were performed with the following equation:

$$C_j(i) = (r_i/Q_j) \exp(-K_i T_j) \quad (1)$$

3,19 where $C_j(i)$ = concentration of the j-th radionuclide at the j-th downstream river location *(Ci/ft^3)*

r_i = reactor effluent mass flow rate *(Ci/d)*

Q_j = Columbia River discharge at location j *(ft^3/d)*

K_i = decay rate (1/d)

20 T_j = travel time from the reactor areas to location j *(d)*

In Equation (1), the concentration of a radionuclide in the river is equal to dilution times decay. Note that Equation (1) is used only to calculate water column concentrations of radionuclides (dissolved); calculations of radionuclide concentrations in the river bed sediments were not done for Phase I. The assumptions implicit in using Equation (1) and the limitations in calculating radionuclide concentrations in the Columbia River are the following:

- On a monthly time scale, the flow and radionuclide transport in the Columbia River reach between Priest Rapids Dam and McNary Dam, and in each sub-reach, can be represented as a succession of steady-state time periods.

- The reactor effluent discharge rates are constant within each given month. The effects of longitudinal dispersion (mixing) are neglected, and complete mixing of effluent at the discharge point is assumed. The reactor effluent discharge rates varied on a daily basis, but the analysis of the effects of unsteady effluent discharges are beyond the scope of the Phase I work.

- Radionuclide concentrations are completely mixed, or uniformly distributed in a cross section of the river, at any location in the reach between Priest Rapids Dam and McNary Dam. Under actual conditions, this assumption is not realistic near the reactor effluent outfalls and for a number of miles downstream, depending on flow conditions in the river. In addition, this assumption does not apply at locations downstream from where tributaries, such as the Yakima, Snake, and Walla Walla rivers, enter the Columbia River.

- The effluent spent a relatively short time in retention basins before discharging to the river, as compared to the half-life of the individual radionuclides. Because the retention time of the effluent was typically 4 hours (Honstead 1967) and the half-lives of the dominant radionuclides in Table 1 range from 0.11 to 245 days, this assumption is reasonable for most of the radionuclides in the Phase I calculations.

- Radionuclide sources and sinks in the river are neglected. Sorption to sediment and subsequent deposition or resuspension of contaminated bed sediment are assumed to be small, compared to the concentrations of radionuclides dissolved in the water column. This assumption is invalid in the McNary Dam reservoir, which is a depositional area for sediment. Also neglected is the uptake of radioactivity by biota within the river system.

Despite these assumptions, Equation (1) provides a useful tool for estimating radionuclide concentrations for Phase I and comparing these estimates with measured concentrations to evaluate the consistency of the available data.

Five sub-reaches of the river between Priest Rapids Dam and McNary Dam were selected for estimating the radionuclide concentrations in the river water for Phase I. These five sub-reaches of the river, designated as Ringold, Richland, Pasco, Finley, and McNary (Figure 1), were selected because they correspond to geographic locations of interest, such as population centers and confluences of the tributaries of the Columbia River. Each tributary enters the Columbia River in a different sub-reach.

The calculations for dilution and decay of radionuclides downstream of the reactors used hydrographs for the Columbia River and its tributaries in the reach between Priest Rapids Dam and McNary Dam. The monthly average discharges or flow rates measured by the USGS for the Columbia River and its tributaries are illustrated in hydrographs in Figures 2 through 6. The average daily and monthly discharges for the Columbia River measured at Priest Rapids Dam are compared in Figure 7. As illustrated in Figure 7, significant differences in dilution of reactor effluent and in travel time can occur daily and weekly. In fact, because Priest Rapids Dam is operated for "power peaking," where discharges are varied on a hourly basis to meet electrical power demand during heavy use periods, the discharge of the Columbia River can vary significantly on an hourly basis.

The average monthly discharges of the Columbia River in each sub-reach for 1964 through 1966 are listed in Table 2. The discharges for each sub-reach were calculated by summing the discharge for the Columbia River and any tributaries entering the sub-reach. Travel times for radionuclides suspended in the water column were estimated with a steady-flow backwater analysis. A set of flow-time curves calculated by the U.S. Army Corps of Engineers, starting from river mile 369 near the 100-F Area, is shown in Figure 8. Using these data, approximate travel times for each sub-reach were estimated (Table 3). These travel-time estimates are used to account for radioactive decay in the various sub-reaches of the river, based on the

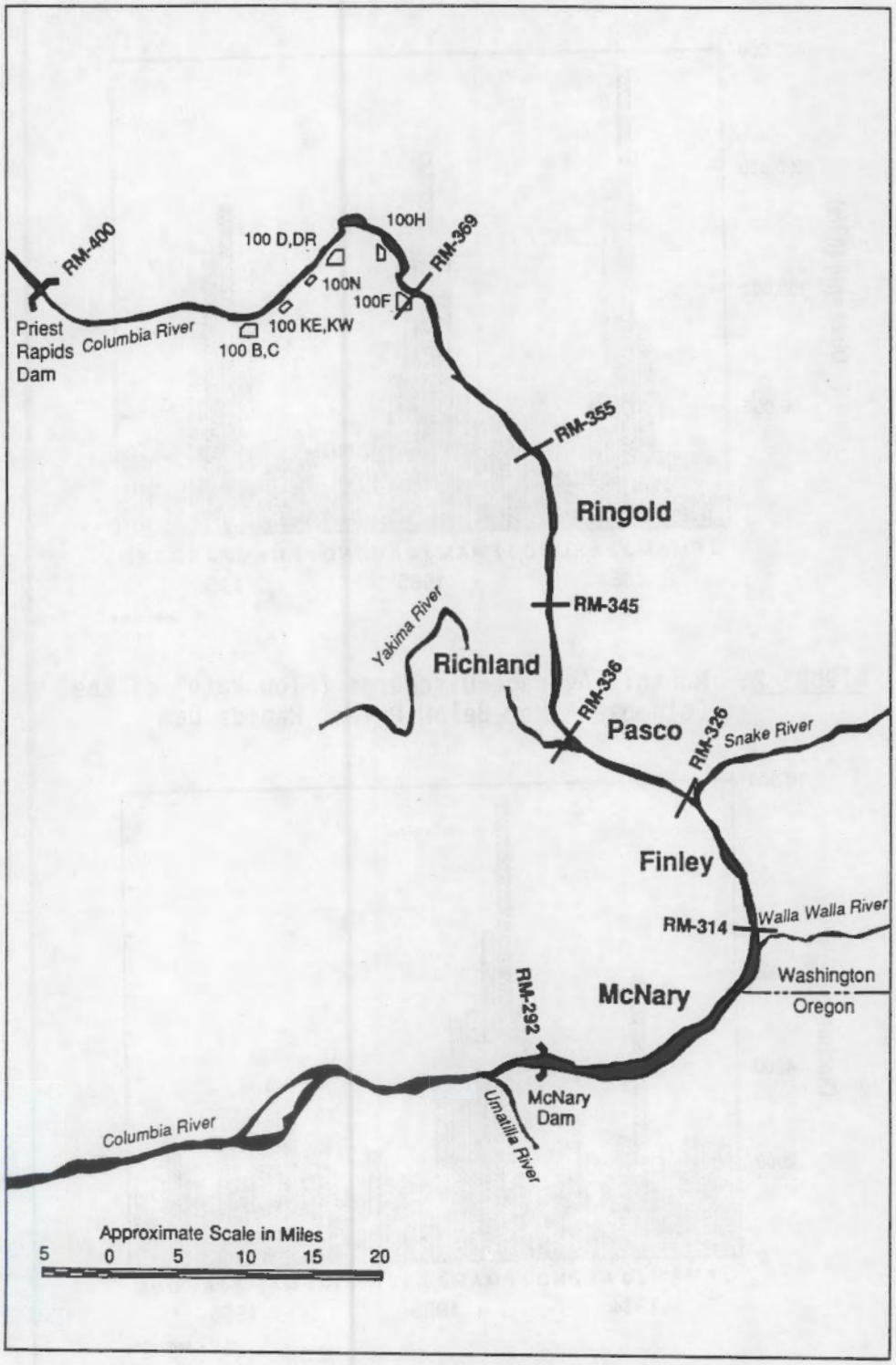


FIGURE 1. Columbia River Sub-Reaches Used in Estimating Radionuclide Concentrations

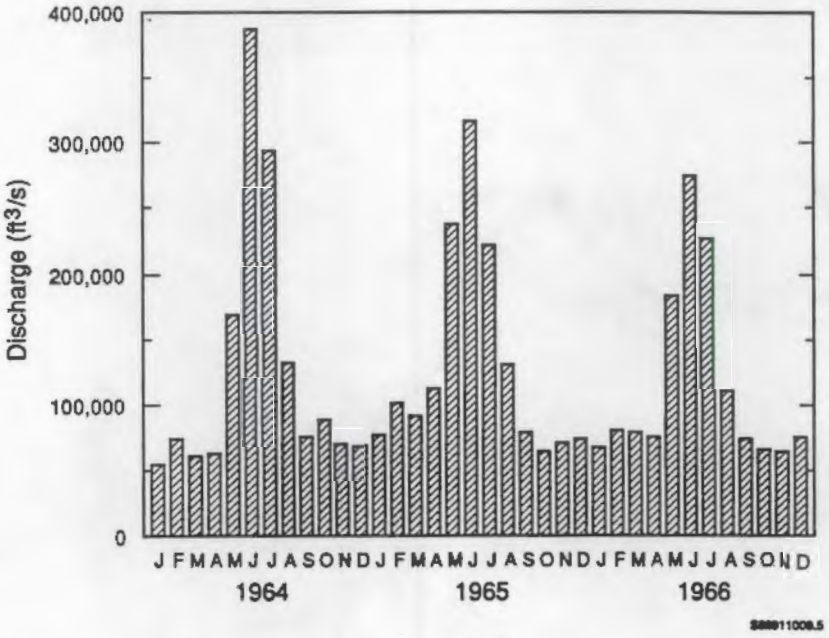


FIGURE 2. Monthly Average Discharge (Flow Rate) of the Columbia River Below Priest Rapids Dam

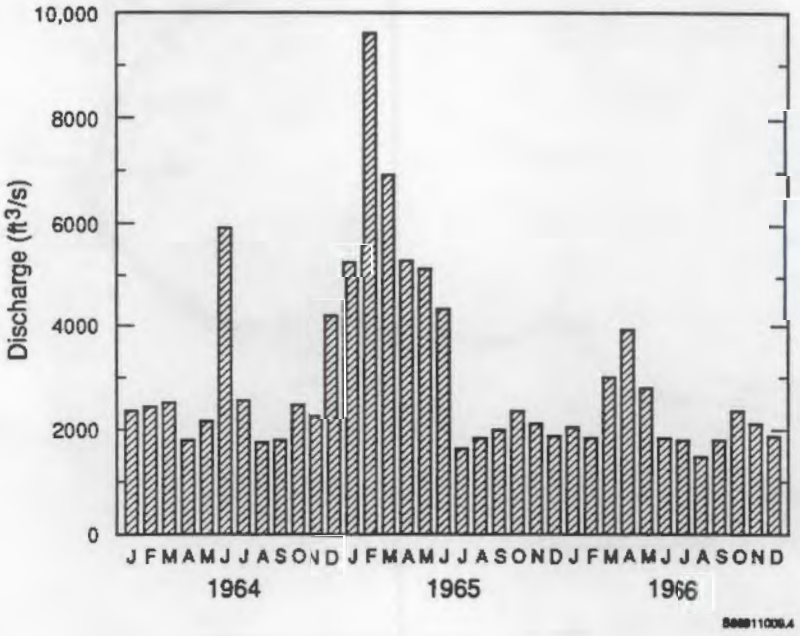


FIGURE 3. Monthly Average Discharge (Flow Rate) of the Yakima River Near Kiona, Washington

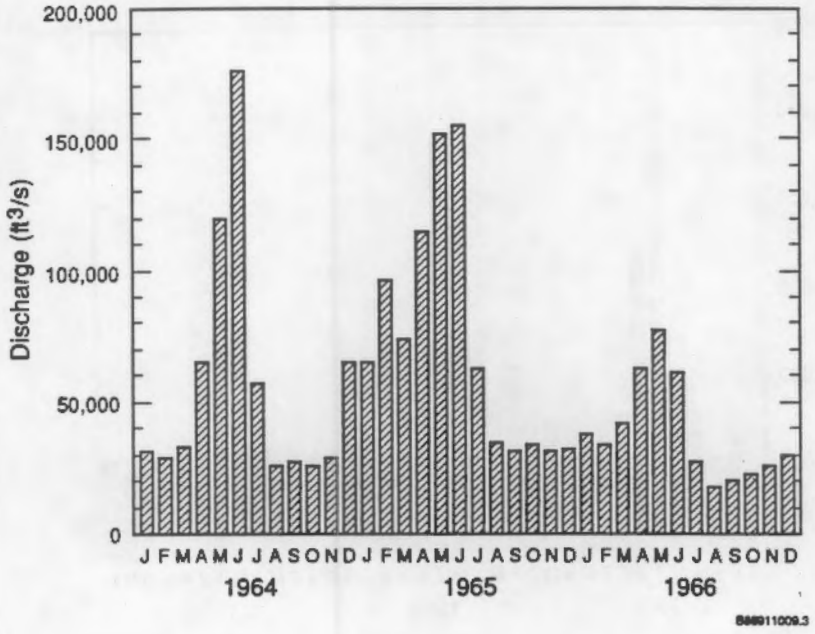


FIGURE 4. Monthly Average Discharge (Flow Rate) of the Snake River Below Ice Harbor Dam

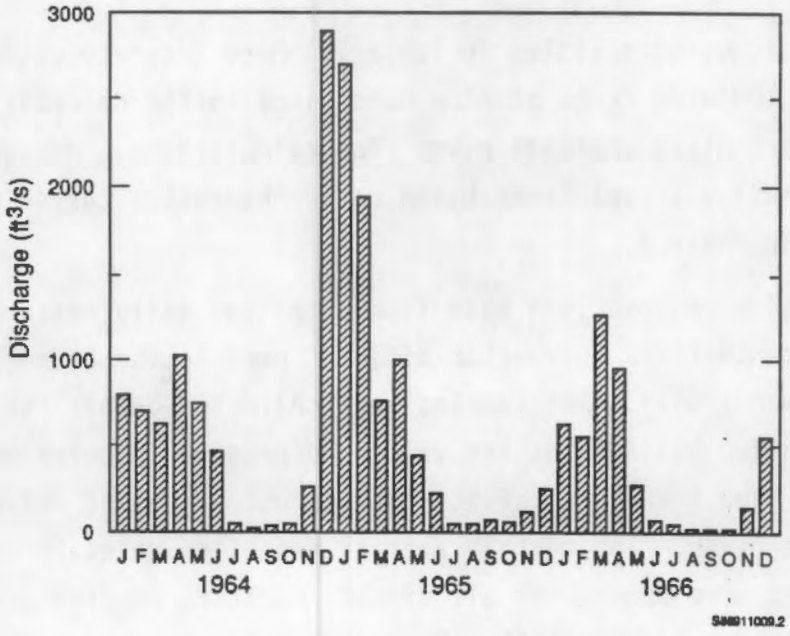


FIGURE 5. Monthly Average Discharge (Flow Rate) of the Walla Walla River Near Touchet, Washington

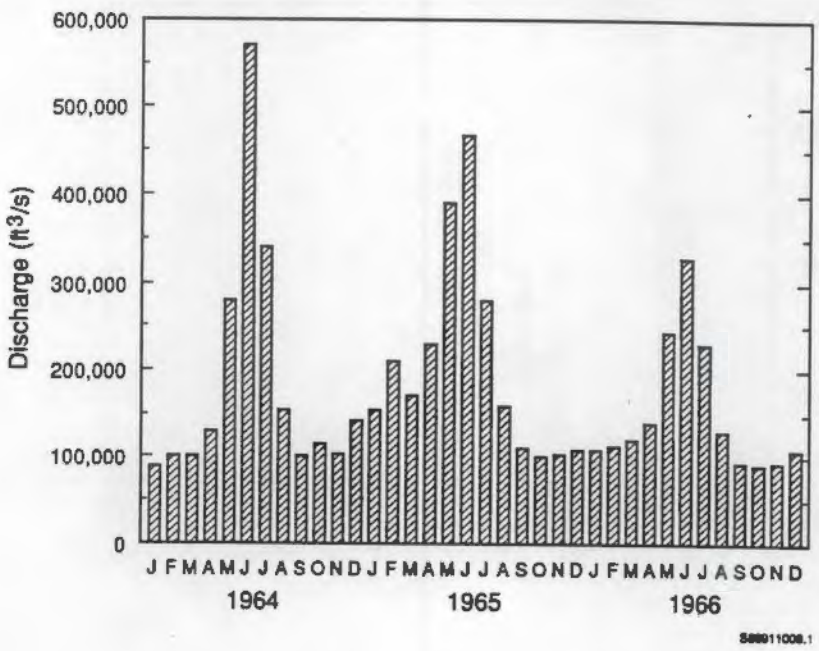


FIGURE 6. Monthly Average Discharge (Flow Rate) of the Columbia River Below McNary Dam

half-lives of radionuclides listed in Table 1. More accurate estimates of travel times for the wide range of flow conditions in the Columbia River could be determined using unsteady river flow calculations. However, the approach of estimating travel times based on the backwater curves was judged to be adequate for Phase I.

Monthly averaged radionuclide mass flow rates and daily measurements of radionuclide concentrations in reactor effluent used in the Phase I calculations are from Owen (1967). The samples were collected before the effluent entered the retention basins, but the values recorded were corrected for 4 hours of decay, and therefore reflect the concentrations of radionuclides discharged to the river. The monthly average mass flow rates for the dominant radionuclides were summed for all of the operating reactors, and are illustrated in Figures 9 through 13. Numerical values of these mass flow rates are summarized in Table 4. Three radionuclides, sodium-24, manganese-56, and copper-64, were not measured continuously during the 1964 through

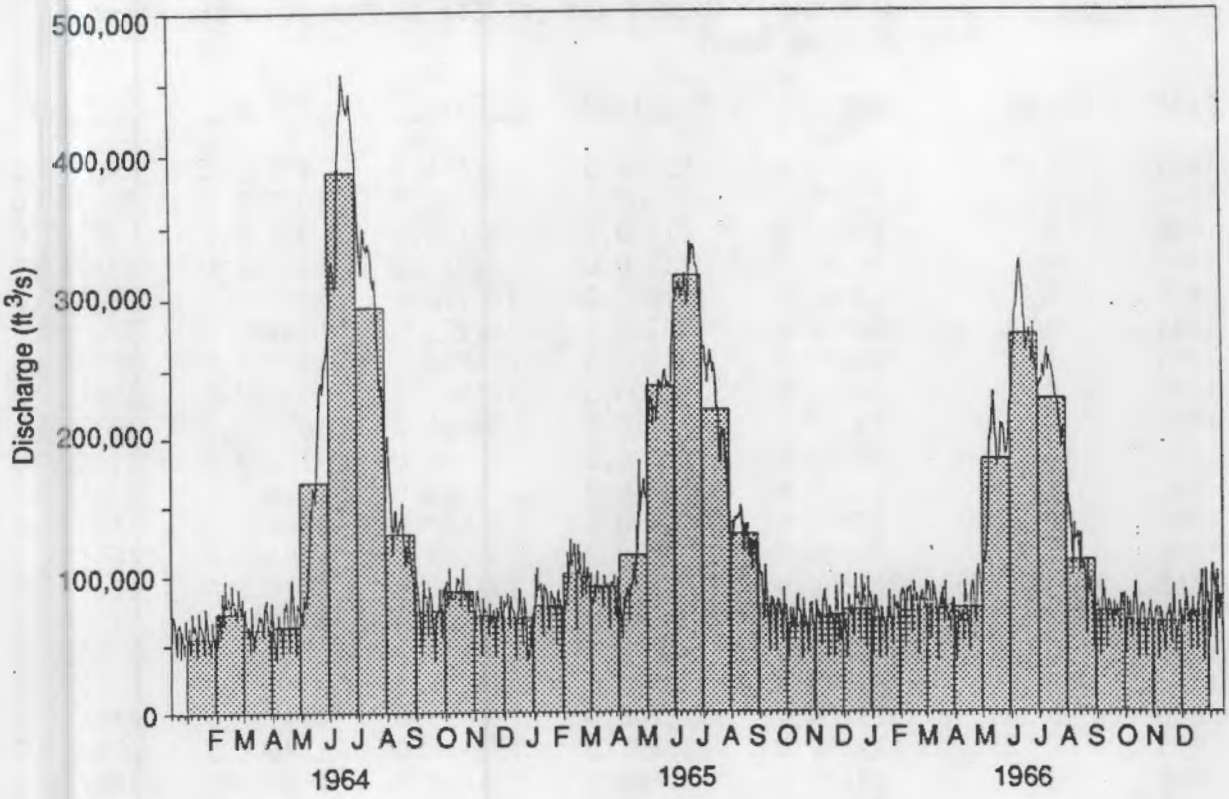


FIGURE 7. Average Daily and Monthly Discharges of the Columbia River at Priest Rapids Dam

1966 time period. The available mass flow rates for these radionuclides are listed in Table 5. In the Phase I dose calculations, the mass flow rates associated with these radionuclides, and hence river concentrations, are assumed to remain constant for the entire 1964 through 1966 time period.

The radionuclide concentrations calculated using Equation (1) are summarized in Appendix A (Tables A.1 through A.40).

TABLE 2. Average Monthly Discharges (ft^3/s) to the Columbia River for Each Sub-Reach

Year	Month	Ringold	Richland	Pasco	Finley	McNary
1964	1	55070.0	55070.0	57411.0	87771.0	88565.0
1964	2	72700.0	72700.0	75132.0	103982.0	104704.0
1964	3	61220.0	61220.0	63760.0	95130.0	95763.0
1964	4	63110.0	63110.0	64912.0	130232.0	131247.0
1964	5	167600.0	167600.0	169771.0	289571.0	290307.0
1964	6	388300.0	388300.0	394229.0	569729.0	570088.0
1964	7	294300.0	294300.0	296880.0	353320.0	353361.5
1964	8	130200.0	130200.0	131932.0	158092.0	158113.2
1964	9	74570.0	74570.0	76396.0	103226.0	103251.4
1964	10	88820.0	88820.0	91294.0	117004.0	117053.6
1964	11	70940.0	70940.0	73220.0	101890.0	102152.0
1964	12	69470.0	69470.0	73667.0	138417.0	141307.0
1965	1	78050.0	78050.0	83359.0	148419.0	151117.0
1965	2	101500.0	101500.0	111105.0	207215.0	209171.0
1965	3	91530.0	91530.0	98461.0	172581.0	173346.0
1965	4	114100.0	114100.0	119361.0	234361.0	235357.0
1965	5	237500.0	237500.0	242631.0	394831.0	395271.0
1965	6	315200.0	315200.0	319526.0	474326.0	474554.0
1965	7	219900.0	219900.0	221568.0	284808.0	284857.8
1965	8	129600.0	129600.0	131428.0	165228.0	165275.3
1965	9	78330.0	78330.0	80318.0	111168.0	111248.1
1965	10	64540.0	64540.0	66895.0	100285.0	100350.0
1965	11	70590.0	70590.0	72708.0	103508.0	103625.0
1965	12	74740.0	74740.0	76635.0	108175.0	108432.0
1966	1	68230.0	68230.0	70284.0	107614.0	108242.0
1966	2	81340.0	81340.0	83169.0	115829.0	116374.0
1966	3	77630.0	77630.0	80635.0	121255.0	122521.0
1966	4	76270.0	76270.0	80194.0	143104.0	144048.0
1966	5	183500.0	183500.0	186315.0	262815.0	263080.0
1966	6	274000.0	274000.0	275860.0	336250.0	336309.9
1966	7	227600.0	227600.0	229405.0	255575.0	255622.8
1966	8	110500.0	110500.0	111963.0	129733.0	129745.3
1966	9	73590.0	73590.0	75394.0	94404.0	94417.9
1966	10	66660.0	66660.0	69015.0	90785.0	90817.2
1966	11	65470.0	65470.0	67588.0	92528.0	92678.0
1966	12	73700.0	73700.0	75595.0	104305.0	104852.0

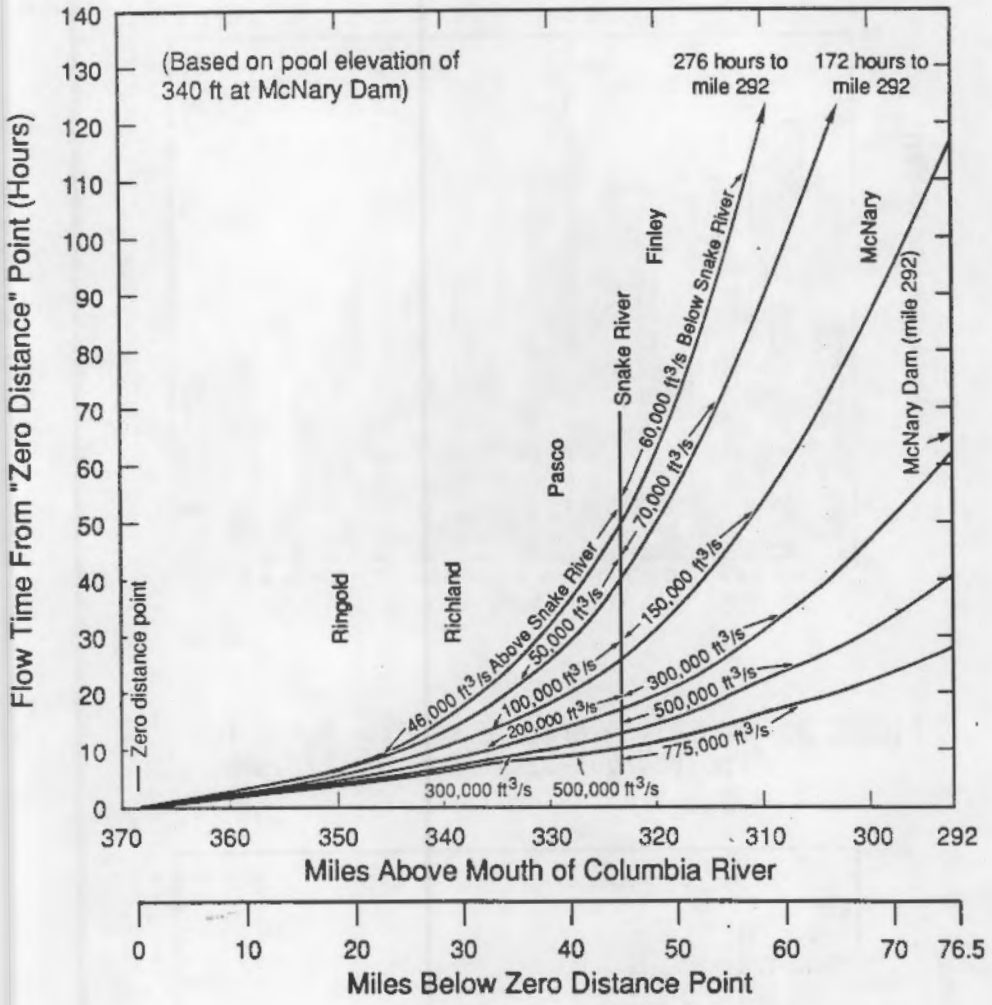


FIGURE 8. Flow Time Curves (after Roebeck et al. 1954)

TABLE 3. Travel Time (hours) from River Mile 369 at the 100-F Area

Reach	Average River Mile	Discharge Above Snake / Discharge Below Snake (ft³/s) 46,000 / 60,000	50,000 / 70,000	100,000 / 150,000	200,000 / 300,000	300,000 / 500,000	500,000 / 775,000
Ringold	350	7	7	6	5	4	3
Richland	340	16	15	11	9	7	6
Pasco	330	34	26	18	13	10	8
Finley	320	65	52	32	20	15	11
McNary	300	-	135	85	48	31	22

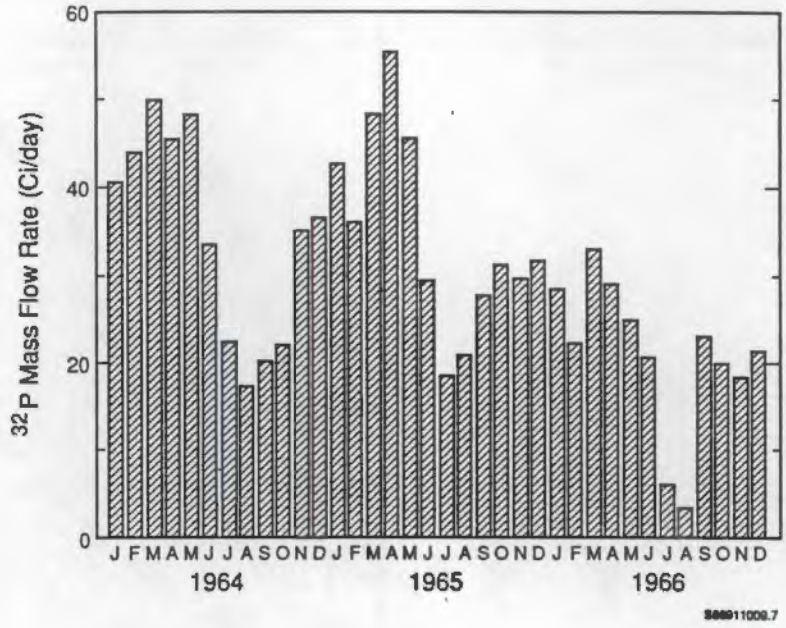


FIGURE 9. Monthly Average Mass Flow Rates for Phosphorous-32 in Reactor Effluent

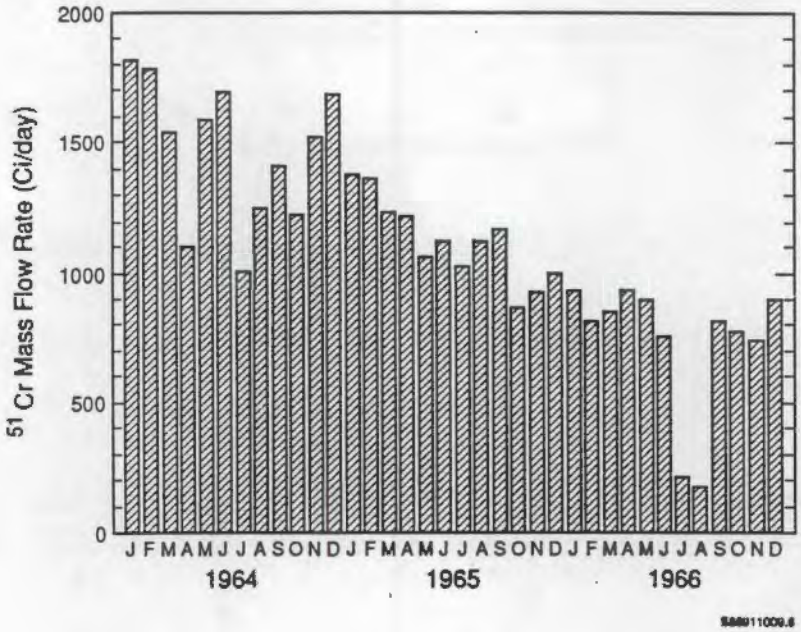


FIGURE 10. Monthly Average Mass Flow Rates for Chromium-51 in Reactor Effluent

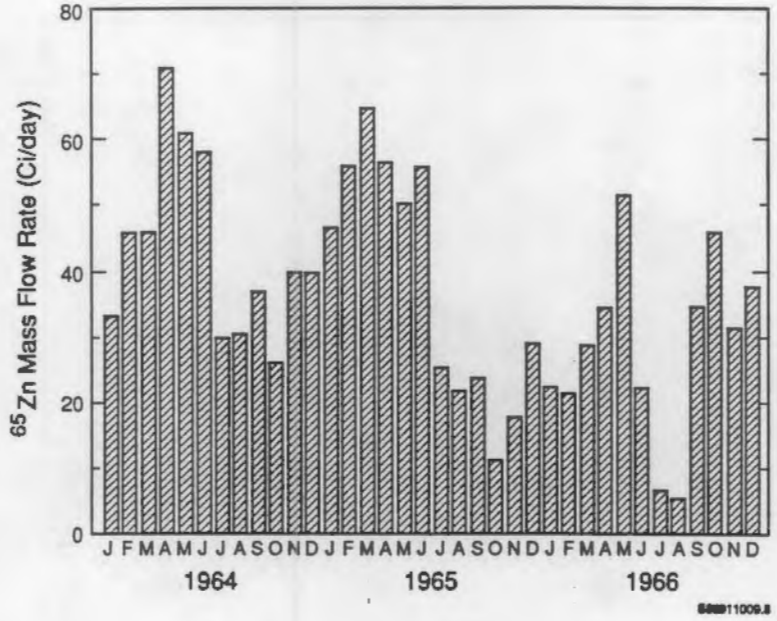


FIGURE 11. Monthly Average Mass Flow Rates for Zinc-65 in Reactor Effluent

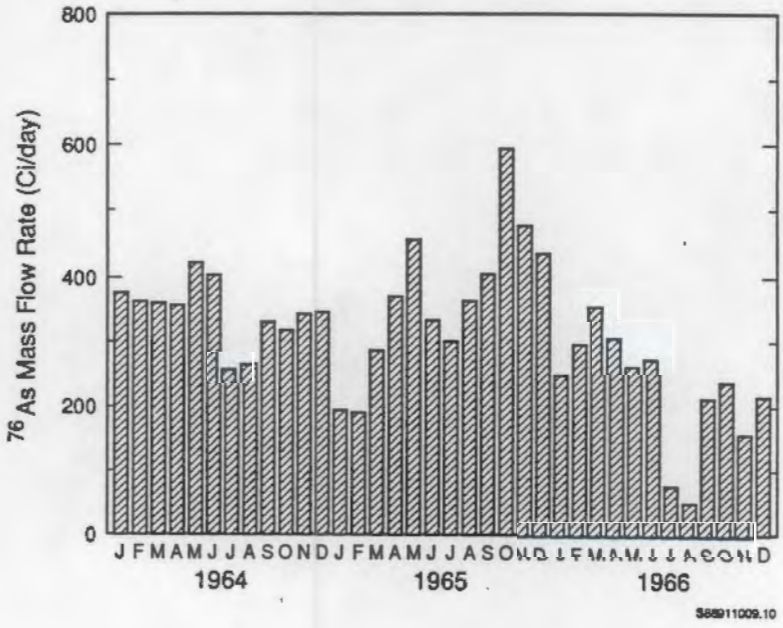


FIGURE 12. Monthly Average Mass Flow Rates for Arsenic-76 in Reactor Effluent

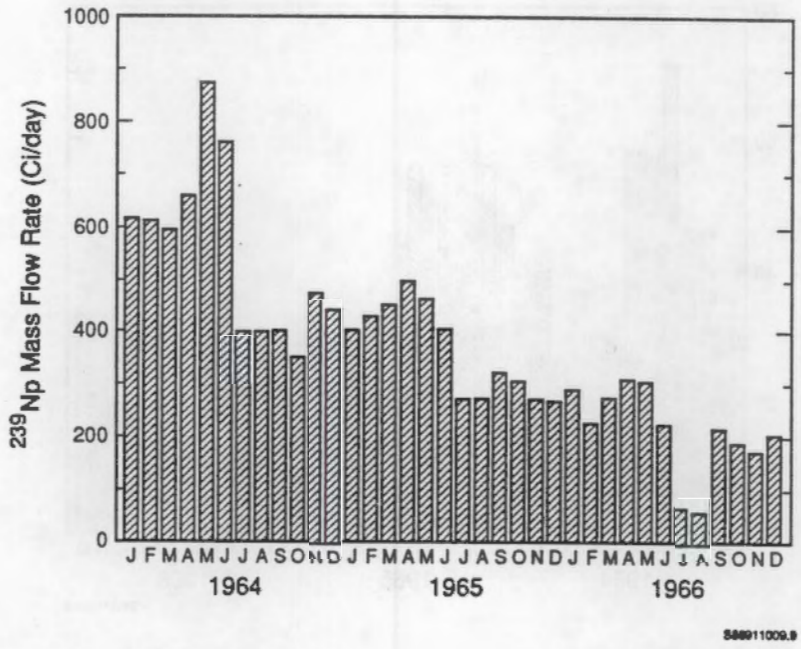


FIGURE 13. Monthly Average Mass Flow Rates for Neptunium-239 in Reactor Effluent

TABLE 4. Daily Average Radionuclide Mass Flow Rates (Ci/Day) Totaled for All Operating Reactors

Year	Month	^{32}P	^{51}Cr	^{65}Zn	^{76}As	^{239}Np
1964	1	40.3	1819.0	33.0	376.0	615.0
1964	2	44.0	1792.0	45.7	362.0	601.0
1964	3	50.0	1546.0	45.8	360.0	593.0
1964	4	45.5	1100.0	71.1	358.0	660.0
1964	5	48.7	1590.0	61.1	421.0	870.0
1964	6	33.6	1700.0	57.9	402.0	760.0
1964	7	22.5	1010.0	30.1	257.0	400.0
1964	8	17.1	1260.0	30.3	262.0	400.0
1964	9	20.4	1420.0	36.8	329.0	400.0
1964	10	22.1	1230.0	26.0	317.0	352.0
1964	11	35.2	1540.0	39.0	340.0	473.0
1964	12	36.6	1690.0	40.0	346.0	442.0
1965	1	43.1	1380.0	46.6	193.0	408.0
1965	2	36.1	1370.0	56.2	192.0	429.0
1965	3	48.8	1240.0	64.7	287.0	453.0
1965	4	55.5	1215.0	56.2	370.0	495.0
1965	5	45.5	1063.0	50.0	454.0	464.0
1965	6	29.7	1130.0	56.0	331.0	405.0
1965	7	18.7	1029.0	25.1	300.0	271.0
1965	8	20.9	1128.0	21.8	360.6	273.0
1965	9	27.5	1178.0	23.5	407.0	320.0
1965	10	31.0	858.0	11.1	595.0	305.0
1965	11	29.7	917.0	17.6	477.0	270.0
1965	12	31.1	999.0	28.9	438.0	266.0
1966	1	28.3	928.0	22.0	246.0	288.0
1966	2	22.5	810.0	20.7	294.0	226.0
1966	3	33.0	849.0	28.7	353.0	273.0
1966	4	29.2	923.0	33.9	305.0	308.0
1966	5	25.1	902.0	51.2	263.0	305.0
1966	6	21.1	759.0	22.0	272.0	220.0
1966	7	6.0	206.0	6.4	74.0	66.0
1966	8	3.2	185.0	5.3	45.6	57.0
1966	9	24.1	818.0	34.7	208.0	214.0
1966	10	20.0	776.0	45.2	232.0	185.0
1966	11	18.3	748.0	31.4	154.0	170.0
1966	12	21.2	897.0	37.3	210.0	206.0

TABLE 5. Mass Flow Rates for Sodium-24, Manganese-56, and Copper-64 Measured for Specific Times

Radionuclide Release Rate for all Reactors (Ci/Day)

Year	Month	^{24}Na	^{56}Mn	^{64}Cu
64	1	3,000	17,000	2,400
64	2	2,500	17,000	2,700
64	3	2,500	18,000	2,300

REFERENCES

Essig, T. H. 1967. Evaluation of Radiological Conditions in the Vicinity of Hanford for 1966 - Appendices. BNWL-439 APP, Pacific Northwest Laboratory, Richland, Washington.

Essig, T. H., and J. K. Soldat, eds. 1967. Evaluation of Radiological Conditions in the Vicinity of Hanford for 1966. BNWL-439, Pacific Northwest Laboratory, Richland, Washington.

Haushild, W. L., H. H. Stevens, Jr., J. L. Nelson, and G. R. Dempster, Jr. 1973. Radionuclides in Transport in the Columbia River from Pasco to Vancouver, Washington. U.S. Geological Survey Prof. Paper 433-N, Washington, D.C.

Haushild, W. L., G. R. Dempster, and H. H. Stevens, Jr. 1975. Distribution of Radionuclides in the Columbia River Streambed, Hanford Reservation to Longview, Washington. U.S. Geological Survey Prof. Paper 433-O, Washington, D.C.

Honstead, J. F. 1967. Evaluation of Radiological Conditions in the Vicinity of Hanford for 1966. BNWL-439, Pacific Northwest Laboratory, Richland, Washington.

Moore, D., and T. H. Essig. 1966. Evaluation of Radiological Conditions in the Vicinity of Hanford for 1965 - Appendices. BNWL-316 APP, Pacific Northwest Laboratory, Richland, Washington.

1 *Morgan, K. Z. 1980. "Permissible Quarterly Intakes of Radionuclides." In Handbook of Chemistry and Physics. 61st ed. CRC Press, Boca Raton, Florida.*

Napier, B. A. 1989. Selection of Dominant Radionuclides for Phase I of the Hanford Environmental Dose Reconstruction Project. PNL-7231 HEDR, Pacific Northwest Laboratory, Richland, Washington.

Nelson, J. L. 1965. Hanford Radiological Sciences Research and Development Annual Report for 1964. BNWL-36, Battelle, Pacific Northwest Laboratories, Richland, Washington.

Owen, F. E. 1967. Reactor Effluent Water Analytical Data 1964, 1965, and 1966. DUN-2457, Douglas United Nuclear, Inc., Richland, Washington.

Roebeck, G. G., D. Hendersen, and R. C. Palange. 1954. Water Quality Studies on the Columbia River. GEH-21328, U.S. Public Health Service, Washington, D.C.

Wilson, R. H., ed. 1965. Evaluation of Radiological Conditions in the Vicinity of Hanford for 1964. BNWL-90, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX A

CALCULATED AND MEASURED WATER CONCENTRATIONS

TABLE A.1. Calculated and Measured Phosphorous-32 Concentrations in the Ringold Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	295.0			
64	2	244.1			
64	3	329.3			
64	4	299.7			
64	5	117.5			
64	6	35.1			
64	7	31.0			
64	8	53.1			
64	9	110.4			
64	10	100.4			
64	11	200.1			
64	12	212.5			
65	1	222.8			
65	2	143.6			
65	3	215.2		230.0	230.0
65	4	196.5		22.0	22.0
65	5	77.6		6.0	6.0
65	6	38.2		8.3	8.3
65	7	34.4		78	78
65	8	65.1		69	69
65	9	141.6		80	80
65	10	193.7		170	170
65	11	169.7		83	83
65	12	167.9			
66	1	167.3		180	180
66	2	111.6		86	86
66	3	171.5		190	190
66	4	154.4		140	140
66	5	55.3		91	91
66	6	31.2		34	34
66	7	10.7		6	6
66	8	11.7		6	6
66	9	132.1		280	280
66	10	121.0		200	200
66	11	112.7		48	48
66	12	116.0		220	220

TABLE A.2. Calculated and Measured Phosphorous-32 Concentrations in the Richland Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	290.4	207.7	420	97
64	2	240.9	264.8	560	240
64	3	324.4	282.3	430	150
64	4	286.5	313.9	630	150
64	5	116.5	195.8	470	120
64	6	34.9	55.5	140	28
64	7	30.8	43.5	73	28
64	8	52.6	78.2	110	54
64	9	108.9	124.0	150	97
64	10	99.3	102.7	150	62
64	11	197.4	220.3	350	120
64	12	209.6	212/3	440	180
65	1	220.0	125.3	160	80
65	2	142.2	70.0	93	31
65	3	212.8	137.8	420	4.4
65	4	194.6	251.7	560	120
65	5	77.0	107.4	220	74
65	6	38.0	64.0	150	26
65	7	34.2	36.4	68	18
65	8	64.4	61.7	140	50
65	9	139.8	108.9	220	71
65	10	190.9	177.1	520	130
65	11	167.4	173.7	460	150
65	12	165.7	188.7	430	200
66	1	165.0	246.8	280	86
66	2	110.2	162.5	370	100
66	3	169.3	221.6	340	180
66	4	152.5	208.3	290	160
66	5	54.9	153.8	180	58
66	6	31.0	48.6	68	28
66	7	10.6	21.9	64	6
66	8	11.6	16.5	99	6
66	9	130.4	128.1	210	85
66	10	119.3	151.0	160	130
66	11	111.1	183.0	300	140
66	12	114.5	152.3	230	120

TABLE A.3. Calculated and Measured Phosphorous-32 Concentrations in the Pasco Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	272.9	184	300	110
64	2	229.0		240	210
64	3	305.5		400	310
64	4	273.2		380	360
64	5	113.9	133.9	370	51
64	6	34.2	38.1	78	33
64	7	30.4	33.1	50	17
64	8	51.2	57.0	75	45
64	9	104.4	76.6	100	24
64	10	95.1	81.2	100	72
64	11	187.8	110.0	170	23
64	12	194.2	126.0	180	180
65	1	202.7	90.3	140	70
65	2	128.2	51.2	76	5
65	3	195.2	63.8	150	9
65	4	183.6	150.7	200	120
65	5	74.9	60.7	120	30
65	6	37.9	32.9	37	21
65	7	33.6	22.9	46	16
65	8	62.8	42.6	66	34
65	9	134.1	88.4	140	30
65	10	180.7	120.7	160	76
65	11	159.6	184.0	200	100
65	12	153.7	156.1	200	150
66	1	157.2		135	111
66	2	105.0		80	80
66	3	160.3		208	208
66	4	142.6		89	89
66	5	53.6		54	40
66	6	30.6		27	12
66	7	10.4			
66	8	11.3			
66	9	125.0			
66	10	113.1			
66	11	105.6			
66	12	109.7			

TABLE A.4. Calculated and Measured Phosphorous-32 Concentrations in the Finley Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	170.5			
64	2	158.4			
64	3	195.9			
64	4	132.5			
64	5	65.9			
64	6	23.4			
64	7	25.1			
64	8	41.5			
64	9	74.0			
64	10	71.2			
64	11	129.2			
64	12	100.7			
65	1	111.2			
65	2	67.4			
65	3	108.7			
65	4	92.0			
65	5	45.5			
65	6	24.8			
65	7	25.7			
65	8	48.5			
65	9	92.9			
65	10	115.5			
65	11	107.4			
65	12	107.9			
66	1	98.6			
66	2	73.2			
66	3	102.8			
66	4	77.9			
66	5	37.3			
66	6	24.7			
66	7	9.1			
66	8	9.4			
66	9	95.1			
66	10	81.9			
66	11	73.6			
66	12	76.1			

TABLE A.5. Calculated and Measured Phosphorous-32 Concentrations in the McNary Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	145.0			
64	2	136.6	88.8	92	82
64	3	167.9	121.5	160	82
64	4	116.6	119.0	160	100
64	5	61.9	61.2	110	14
64	6	22.7	11.1	17	8.1
64	7	23.8	24.1	30	16
64	8	37.4	34.4	44	29
64	9	64.1	44.5	61	21
64	10	62.4	55.1	67	39
64	11	111.7	119.2	190	85
64	12	88.2	190.0	190	190
65	1	98.2	47.8	89	8
65	2	61.2	30.4	67	8
65	3	93.1	62.6	120	19
65	4	84.7	73.4	91	11
65	5	43.4	30.0	44	12
65	6	23.9	12.0	18	8
65	7	24.2	15.7	22	3
65	8	43.8	26.5	36	7
65	9	81.0	41.2	47	7
65	10	99.9	55.5	67	16
65	11	93.1	125.3	95	42
65	12	93.7	165.3	130	49
66	1	85.4	187.7	710	45
66	2	63.8	202.2	710	46
66	3	89.6	93.7	110	78
66	4	69.3	84.8	130	44
66	5	34.7	68.2	130	23
66	6	23.4	36.5	52	23
66	7	8.5	18.9	41	6
66	8	8.3	6.0	6	6
66	9	81.9	42.2	50	6
66	10	70.4	63.6	98	47
66	11	63.2	59.6	67	52
66	12	65.8	61.4	80	41

TABLE A.6. Calculated and Measured Neptunium-239 Concentrations in the Ringold Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	4190.4			
64	2	3115.5			
64	3	3640.1			
64	4	3931.9			
64	5	1986.1			
64	6	765.4			
64	7	528.3			
64	8	1170.0			
64	9	2022.5			
64	10	1899.5			
64	11	2511.7			
64	12	2395.9			
65	1	1972.7			
65	2	1604.0			
65	3	1873.9		2200	2200
65	4	1648.9		68	68
65	5	754.0		15	15
65	6	500.2		42	42
65	7	474.6		700	700
65	8	802.2		650	650
65	9	1541.8		460	460
65	10	177.4		1000	1000
65	11	1440.7		450	450
65	12	1342.0			
66	1	1589.0		290	290
66	2	1049.4		650	650
66	3	1326.9		540	540
66	4	1523.2		580	580
66	5	637.2		420	420
66	6	311.3		280	280
66	7	111.8		10	10
66	8	196.0		10	10
66	9	1096.2		590	590
66	10	1044.3		690	690
66	11	976.8		410	410
66	12	1053.7		1100	1100

TABLE A.7. Calculated and Measured Neptunium-239 Concentrations in the Richland Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	3809.2		3100	3100
64	2	2869.5		4200	4200
64	3	3324.2		3200	3000
64	4	3595.7		5600	4800
64	5	1882.5		3600	2800
64	6	737.5		970	860
64	7	508.6		760	640
64	8	1103.9		1600	1600
64	9	1865.4		2400	2400
64	10	1397.8		1400	1400
64	11	2310.3		2900	2900
64	12	2201.4		2800	2800
65	1	1824.1		2500	2500
65	2	1507.9			
65	3	1750.3			
65	4	1552.6		2700	2700
65	5	720.9		1000	1000
65	6	482.0		1100	1100
65	7	452.8		320	320
65	8	756.8		930	930
65	9	1426.0		1500	1500
65	10	1627.1		2500	2500
65	11	1324.9		2000	2000
65	12	1237.9		2000	2000
66	1	1458.7		480	480
66	2	972.7		830	830
66	3	1226.6		1700	1700
66	4	1806.7		1000	1000
66	5	605.2		680	680
66	6	299.0		310	310
56	7	106.7		10	10
56	8	184.4		10	10
56	9	1010.3		730	730
56	10	957.6		780	780
56	11	894.9		1400	1400
66	12	971.2		1300	1300

TABLE A.8. Calculated and Measured Neptunium-239 Concentrations in the Pasco Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	3219.2		1700	1200
64	2	2489.9		1500	1500
64	3	2830.4		2300	2100
64	4	3101.3		2200	1900
64	5	1749.7		1700	1300
64	6	704.3		710	550
64	7	485.9		420	310
64	8	1011.2		1300	990
64	9	1633.8			
64	10	1239.2			
64	11	2003.2			
64	12	1862.2			
65	1	1548.5			
65	2	1271.3			
65	3	1499.9			
65	4	1372.4			
65	5	675.9			
65	6	458.8			
65	7	428.9			
65	8	692.6			
65	9	1252.9			
65	10	1396.2			
65	11	1150.3			
65	12	1083.6			
66	1	1263.3			
66	2	859.4			
66	3	1065.4			
66	4	1207.4			
66	5	564.7			
66	6	285.4			
66	7	101.2			
66	8	167.7			
66	9	884.0			
66	10	824.3			
66	11	771.3			
66	12	849.0			

TABLE A.9. Calculated and Measured Neptunium-239 Concentrations in the Finley Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	1583.5			
64	2	1377.8			
64	3	1445.8			
64	4	1310.5			
64	5	948.5			
64	6	458.5			
64	7	367.2			
64	8	701.2			
64	9	921.6			
64	10	746.7			
64	11	1099.5			
64	12	846.9			
65	1	752.0			
65	2	602.4			
65	3	737.9			
65	4	631.3			
65	5	386.1			
65	6	287.5			
65	7	299.0			
65	8	461.1			
65	9	701.6			
65	10	716.7			
65	11	620.9			
65	12	593.3			
66	1	645.2			
66	2	482.5			
66	3	566.2			
66	4	579.2			
66	5	356.8			
66	6	211.1			
66	7	78.8			
56	8	113.4			
66	9	524.6			
66	10	466.3			
66	11	422.7			
66	12	471.3			

TABLE A.10. Calculated and Measured Neptunium-239 Concentrations in the McNary Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	615.0			
64	2	576.1			
64	3	579.9			
64	4	619.9			
64	5	656.0			
64	6	381.8			
64	7	270.0			
64	8	369.7			
64	9	384.5			
64	10	332.1			
64	11	455.6			
64	12	416.8			
65	1	386.2			
65	2	350.3			
65	3	400.1			
65	4	389.2			
65	5	292.6			
65	6	231.3			
65	7	204.8			
65	8	246.7			
65	9	303.7			
65	10	294.9			
65	11	259.3			
65	12	253.4			
66	1	274.5			
66	2	213.3			
66	3	256.7			
66	4	291.0			
66	5	233.5			
66	6	153.2			
66	7	50.8			
66	8	53.5			
66	9	210.1			
66	10	183.6			
66	11	167.7			
66	12	187.4			

TABLE A.11. Calculated and Measured Zinc-65 Concentrations in the Ringold Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	244.7			
64	2	256.7			
64	3	305.5			
64	4	460.1			
64	5	148.9			
64	6	60.9			
64	7	41.8			
64	8	95.1			
64	9	201.5			
64	10	119.6			
64	11	224.5			
64	12	235.2			
65	1	243.8			
65	2	226.1			
65	3	288.7			
65	4	201.2			
65	5	86.0			
65	6	72.6			
65	7	46.6			
65	8	68.7			
65	9	122.5			
65	10	70.2			
65	11	101.8			
65	12	157.9			
66	1	131.7			
66	2	103.9			
66	3	151.0			
66	4	181.6			
66	5	114.0			
66	6	32.8			
66	7	11.5			
66	8	19.6			
66	9	192.6			
66	10	276.9			
66	11	195.9			
66	12	206.7			

TABLE A.12. Calculated and Measured Zinc-65 Concentrations in the Richland Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	244.5	292.3	780	260
64	2	256.5	297.2	1800	270
64	3	305.3	322.9	460	320
64	4	459.7	455.7	1000	600
64	5	148.8	220.6	770	150
64	6	60.9	116.4	170	63
64	7	41.8	90.6	256	70
64	8	95.0	135.5	150	120
64	9	201.4	205.0	270	130
64	10	119.5	181.6	220	130
64	11	224.3	320.3	570	220
64	12	235.0	382.1	570	370
65	1	243.7	368.4	650	280
65	2	226.0	419.3	650	370
65	3	288.5	443.1	520	370
65	4	201.1	376.7	440	180
65	5	86.0	201.0	280	150
65	6	72.6	185.0	170	120
65	7	86.6	99.0	144	66
65	8	68.7	148.1	160	79
65	9	122.4	187.7	170	100
65	10	70.2	150.0	190	130
65	11	101.7	142.0	170	120
65	12	157.8	113.2	180	130
66	1	131.6	223.2	429	69
66	2	103.9	180.0	200	120
66	3	150.9	262.6	450	190
66	4	181.5	410.0	530	170
66	5	113.9	483.8	680	180
66	6	32.8	205.4	350	67
66	7	11.5	62.4	140	20
66	8	19.6	36.2	120	20
66	9	192.4	118.7	160	59
66	10	276.7	148.7	170	110
66	11	195.7	189.0	340	120
66	12	206.5	180.4	190	170

TABLE A.13. Calculated and Measured Zinc-65 Concentrations in the Pasco Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	234.2	320	460	190
64	2	248.0		210	94
64	3	292.8		319	250
64	4	446.4		320	236
64	5	146.8	178.0	610	107
64	6	60.0	64.8	109	39
64	7	41.4	46.4	63	27
64	8	93.7	82.3	130	54
64	9	196.4	128.4	140	63
64	10	116.1	131.3	261	100
64	11	217.1	208.3	280	150
64	12	221.3	228.1	300	234
65	1	227.9	209.0	270	110
65	2	206.3	258.9	320	205
65	3	263.0	320.6	391	170
65	4	192.1	308.0	440	260
65	5	84.1	159.0	220	74
65	6	71.5	99.6	110	49
65	7	46.2	59.2	79	48
65	8	67.7	72.3	86	46
65	9	119.3	98.5	120	66
65	10	67.6	101.5	110	13
65	11	98.7	120.0	140	51
65	12	153.7	109.3	140	98
66	1	127.6		146	126
66	2	101.5		145	123
66	3	145.1		232	195
66	4	172.4		264	76
66	5	112.1		148	79
66	6	32.6		48	40
66	7	11.8		65	3.3
66	8	19.3		75	3.5
66	9	187.6		99	81
66	10	267.0			
66	11	189.4			
66	12	201.1			

TABLE A.14. Calculated and Measured Zinc-65 Concentrations in the Finley Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	152.8			
64	2	178.7			
64	3	195.7			
64	4	222.2			
64	5	86.0			
64	6	41.5			
64	7	34.7			
64	8	78.0			
64	9	145.0			
64	10	90.4			
64	11	155.6			
64	12	117.6			
65	1	127.8			
65	2	110.5			
65	3	152.7			
65	4	97.7			
65	5	51.7			
65	6	48.2			
65	7	35.9			
65	8	53.7			
65	9	86.0			
65	10	45.0			
65	11	69.1			
65	12	108.6			
66	1	83.1			
66	2	72.7			
66	3	96.3			
66	4	96.5			
66	5	79.4			
66	6	26.7			
66	7	10.2			
66	8	16.6			
66	9	149.4			
66	10	202.4			
66	11	137.9			
66	12	145.4			

TABLE A.15. Calculated and Measured Zinc-65 Concentrations in the McNary Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	150.1			
64	2	176.0	115.9	120	120
64	3	192.8	139.4	160	120
64	4	218.9	94.3	140	65
64	5	85.5	55.5	71	26
64	6	41.4	29.2	42	16
64	7	34.6	36.5	50	22
64	8	77.6	40.6	51	21
64	9	143.7	41.1	56	21
64	10	89.7	61.0	120	52
64	11	153.9	108.8	120	95
64	12	114.5	180.0	190	95
65	1	124.8	90.2	130	35
65	2	108.9	99.5	120	50
65	3	151.1	127.9	200	68
65	4	96.9	127.7	200	65
65	5	51.5	55.5	64	28
65	6	48.0	25.8	36	20
65	7	35.3	34.8	44	29
65	8	53.4	25.8	32	20
65	9	85.2	32.9	46	3.5
65	10	44.6	35.8	41	1.0
65	11	68.5	105.5	52	4.6
65	12	107.5	181.1	170	9.5
66	1	82.0	91.6	99	44
66	2	71.8	105.9	120	67
66	3	94.6	101.7	120	77
66	4	95.2	73.9	100	46
66	5	79.0	67.9	74	46
66	6	26.6	72.1	92	41
66	7	10.2	31.7	47	16
66	8	16.5	20.4	23	9.5
66	9	148.1	20.8	23	18
66	10	200.5	33.7	44	20
66	11	136.5	51.1	60	40
66	12	143.5	70.4	92	44

TABLE A.16. Calculated and Measured Arsenic-76 Concentrations in the Ringold Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	2328.3			
64	2	1713.8			
64	3	2011.8			
64	4	1942.6			
64	5	892.8			
64	6	385.4			
64	7	320.9			
64	8	708.2			
64	9	1520.0			
64	10	1238.9			
64	11	1648.1			
64	12	1711.3			
65	1	853.5			
65	2	660.7			
65	3	1090.0		650	650
65	4	1136.4		65	65
65	5	692.0		5	5
65	6	387.2		36	36
65	7	491.6		490	490
65	8	979.1		480	480
65	9	1793.7		230	230
65	10	3159.5		1100	1100
65	11	2323.2		310	310
65	12	2019.2			
66	1	1238.0		610	610
66	2	1249.7		520	520
66	3	1569.1		450	450
66	4	1379.0		340	340
66	5	511.5		250	250
66	6	362.8		89	89
66	7	117.4		5	5
66	8	144.5		5	5
66	9	973.3		370	370
66	10	1194.1		420	420
66	11	806.5		270	270
66	12	981.2		540	540

TABLE A.17. Calculated and Measured Arsenic-76 Concentrations in the Richland Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	1902.5		880	880
64	2	1439.8		2200	2200
64	3	1659.8		2300	1700
64	4	1607.5		2400	2200
64	5	797.0		1300	1100
64	6	356.2		460	450
64	7	296.1		370	300
64	8	626.0		900	900
64	9	1280.7		740	740
64	10	1067.5		760	760
64	11	1380.7		1500	1500
64	12	1430.4		1700	1700
65	1	723.1		1000	1000
65	2	579.7		840	840
65	3	983.2			
65	4	1000.3		1200	1200
65	5	629.2		410	410
65	6	357.9		450	450
65	7	484.9		170	170
65	8	865.3		580	580
65	9	1520.3		1400	1400
65	10	2620.4		2900	2900
65	11	1945.2		1300	1300
65	12	1701.8		1200	1200
66	1	1032.8		440	440
66	2	1064.2		730	730
66	3	1328.5		870	870
66	4	1165.0		490	490
66	5	458.5		411	411
66	6	333.1		140	140
66	7	106.5		5	5
66	8	127.1		5	5
66	9	818.8		240	240
66	10	993.7		900	900
66	11	669.9		420	420
66	12	825.6		410	410

TABLE A.18. Calculated and Measured Arsenic-76 Concentrations in the Pasco Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	1395.5		560	530
64	2	1106.0		750	730
64	3	1235.6		1200	920
64	4	1212.8		1200	860
64	5	692.5		850	670
64	6	328.6		440	350
64	7	271.5		200	180
64	8	527.7		640	470
64	9	993.8			
64	10	853.0			
64	11	1057.3			
64	12	1071.5			
65	1	550.1			
65	2	446.8			
65	3	738.0			
65	4	810.2			
65	5	562.2			
65	6	327.3			
65	7	400.1			
65	8	728.6			
65	9	1188.8			
65	10	1972.2			
65	11	1490.6			
65	12	1320.2			
66	1	787.2			
66	2	839.3			
66	3	1028.4			
66	4	891.8			
66	5	402.8			
66	6	304.1			
66	7	95.9			
66	8	105.4			
66	9	634.0			
66	10	752.0			
66	11	506.7			
66	12	638.9			

TABLE A.19. Calculated and Measured Arsenic-76 Concentrations in the Finley Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	502.5			
64	2	454.2			
64	3	465.8			
64	4	426.0			
64	5	343.9			
64	6	199.8			
64	7	182.1			
64	8	297.4			
64	9	413.7			
64	10	385.0			
64	11	829.4			
64	12	808.8			
65	1	227.1			
65	2	184.4			
65	3	307.7			
65	4	332.6			
65	5	295.9			
65	6	189.2			
65	7	286.7			
65	8	397.6			
65	9	500.7			
65	10	755.4			
65	11	599.3			
65	12	542.9			
66	1	305.4			
66	2	357.9			
66	3	425.4			
66	4	359.4			
66	5	223.8			
66	6	200.3			
66	7	63.8			
66	8	54.3			
66	9	269.9			
66	10	305.7			
66	11	201.4			
66	12	263.2			

TABLE A.20. Calculated and Measured Arsenic-76 Concentrations in the McNary Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	68.0			
64	2	72.2			
64	3	67.8			
64	4	88.0			
64	5	157.9			
64	6	135.7			
64	7	95.0			
64	8	76.7			
64	9	65.0			
64	10	69.2			
64	11	66.6			
64	12	93.2			
65	1	56.5			
65	2	59.1			
65	3	84.5			
65	4	119.9			
65	5	164.7			
65	6	119.4			
65	7	110.7			
65	8	105.7			
65	9	85.0			
65	10	115.2			
65	11	94.4			
65	12	89.6			
66	1	50.3			
66	2	63.9			
66	3	80.6			
66	4	84.3			
66	5	91.3			
66	6	101.7			
66	7	25.2			
66	8	11.1			
66	9	38.8			
66	10	82.5			
66	11	28.5			
66	12	41.9			

TABLE A.21. Calculated and Measured Copper-64 Concentrations in the Ringold Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	12,231			
64	2	10,653			
64	3	10,602			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3			2700	2700
65	4			200	200
65	5			32	32
65	6			110	110
65	7			2000	2000
65	8			1600	1600
65	9			1500	1500
65	10			2400	2400
65	11			1100	1100
65	12				
66	1			1700	1700
66	2			2600	2600
66	3			2500	2500
66	4			2000	2000
66	5			1400	1400
66	6			760	760
66	7			20	20
66	8			70	70
66	9			2100	2100
66	10			2500	2500
66	11			1700	1700
66	12			4000	4000

TABLE A.22. Calculated and Measured Copper-64 Concentrations in the Richland Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	8040		3,300	3,300
64	2	7395		10,000	10,000
64	3	7123		7,000	5,300
64	4			7,400	5,800
64	5			5,600	5,300
64	6			2,400	2,100
64	7			2,300	1,700
64	8			5,700	5,700
64	9			990	990
64	10			4,300	4,300
64	11			6,300	6,300
64	12			10,000	10,000
65	1				
65	2				
65	3				
65	4			770	770
65	5			1,000	1,000
65	6			1,500	1,500
65	7			510	510
65	8			720	720
65	9			430	430
65	10			660	660
65	11			480	480
65	12			900	900
66	1			820	820
66	2			1,900	1,900
66	3			3,000	3,000
66	4			2,100	2,100
66	5			2,700	2,700
66	6			750	750
66	7			48	48
66	8			20	20
66	9			1,000	1,000
66	10			1,400	1,400
66	11			1,500	1,500
66	12			1,800	1,800

TABLE A.23. Calculated and Measured Copper-64 Concentrations in the Pasco Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	4424		830	790
64	2	4430		1900	1300
64	3	4032		3100	2600
64	4			1800	1300
64	5			4800	3100
64	6			1900	1700
64	7			1200	1200
64	8			2500	2200
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.24. Calculated and Measured Copper-64 Concentrations in the Finley Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	836			
64	2	992			
64	3	820			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.25. Calculated and Measured Copper-64 Concentrations in the McNary Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	13			
64	2	22			
64	3	15			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.26. Calculated and Measured Manganese-56 Concentrations in the Ringold Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	20,623			
64	2	17,351			
64	3	20,165			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3			300	300
65	4			28	28
65	5			29	29
65	6			130	130
65	7			570	570
65	8			140	140
65	9			10	10
65	10			91	91
65	11			90	90
65	12				
66	1			940	940
66	2			1600	1600
66	3			2700	2700
66	4			8900	8900
66	5			2000	2000
66	6			820	820
66	7			50	50
66	8			50	50
66	9			720	720
66	10			880	880
66	11			540	540
66	12			810	810

TABLE A.27. Calculated and Measured Manganese-56 Concentrations in the Richland Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	2732			
64	2	2989			
64	3	2967			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.28. Calculated and Measured Manganese-56 Concentrations in the Pasco Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	180			
64	2	287			
64	3	223			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.29. Calculated and Measured Manganese-56 Concentrations in the Finley Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	0.3			
64	2	0.3			
64	3	0.5			
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.30. Calculated and Measured Manganese-56 Concentrations in the McNary Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1				
64	2				
64	3				
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.31. Calculated and Measured Sodium-24 Concentrations in the Ringold Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	16,229			
64	2	10,434			
64	3	12,221			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3			3700	3700
65	4			260	260
65	5			35	35
65	6			110	110
65	7			1600	1600
65	8			1700	1700
65	9			1600	1600
65	10			2300	2300
65	11			1800	1800
65	12				
66	1			810	810
66	2			960	960
66	3			790	790
66	4			830	830
66	5			870	870
66	6			510	510
66	7			18	18
66	8			8	8
66	9			610	610
66	10			710	710
66	11			620	620
66	12			1100	1100

TABLE A.32. Calculated and Measured Sodium-24 Concentrations in the Richland Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	11,403		2200	2200
64	2	7,675		4600	4600
64	3	8,746		4800	4600
64	4			5600	5500
64	5			5300	4300
64	6			1400	1100
64	7			1300	1200
64	8			3300	3300
64	9			2700	2700
64	10			2400	2400
64	11			4700	4700
64	12			5200	5200
65	1				
65	2				
65	3				
65	4			4700	4700
65	5			2000	2000
65	6			2000	2000
65	7			860	860
65	8			2100	2100
65	9			3000	3000
65	10			4000	4000
65	11			3800	3800
65	12			5100	5100
66	1			2700	2700
66	2			4500	4500
66	3			5500	5500
66	4			3700	3700
66	5			3300	3300
66	6			1100	1100
66	7			35	35
66	8			35	35
66	9			1200	1200
66	10			1900	1900
66	11			2800	2800
66	12			4000	4000

TABLE A.33. Calculated and Measured Sodium-24 Concentrations in the Pasco Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	6853		1000	810
64	2	4962		1300	1200
64	3	5384		2600	1900
64	4			1800	1000
64	5			2300	1900
64	6			1100	930
64	7			750	750
64	8			2500	1700
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.34. Calculated and Measured Sodium-24 Concentrations in the Finley Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	1577			
64	2	1338			
64	3	1323			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.35. Calculated and Measured Sodium-24 Concentrations in the McNary Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	48			
64	2	54			
64	3	46			
64	4				
64	5				
64	6				
64	7				
64	8				
64	9				
64	10				
64	11				
64	12				
65	1				
65	2				
65	3				
65	4				
65	5				
65	6				
65	7				
65	8				
65	9				
65	10				
65	11				
65	12				
66	1				
66	2				
66	3				
66	4				
66	5				
66	6				
66	7				
66	8				
66	9				
66	10				
66	11				
66	12				

TABLE A.36. Calculated and Measured Chromium-51 Concentrations in the Ringold Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	13,403.8			
64	2	10,006.3			
64	3	10,249.0			
64	4	7,074.2			
64	5	3,856.0			
64	6	1,782.8			
64	7	1,396.8			
64	8	3,932.0			
64	9	7,730.5			
64	10	5,623.5			
64	11	8,812.1			
64	12	9,874.8			
65	1	7,178.3			
65	2	5,482.5			
65	3	5,501.7		4000	4000
65	4	4,325.8		470	470
65	5	1,820.6		70	70
65	6	1,459.3		140	140
65	7	1,903.0		2400	2400
65	8	3,536.3		2200	2200
65	9	6,105.7		1900	1900
65	10	5,395.8		3300	3300
65	11	5,273.2		1400	1400
65	12	5,426.2			
66	1	5,520.8		3900	3900
66	2	4,043.2		3800	3800
66	3	4,440.1		3300	3300
66	4	4,913.0		2900	2900
66	5	1,998.3		1500	1500
66	6	1,127.2		900	900
66	7	368.1		70	70
66	8	680.1		70	70
66	9	4,512.4		2500	2500
66	10	4,725.1		2900	2900
66	11	4,637.3		1600	1600
66	12	4,940.9		4900	4900

TABLE A.37. Calculated and Measured Chromium-51 Concentrations in the Richland Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	13,287.0	10,380.6	14,000	7,800
64	2	9,937.5	12,572.4	25,000	9,800
64	3	10,171.3	13,096.8	15,000	8,400
64	4	7,021.4	16,366.7	39,000	7,500
64	5	3,838.8	4,216.1	10,000	1,800
64	6	1,777.2	2,340.0	2,700	1,800
64	7	1,392.3	2,358.1	4,100	1,700
64	8	3,912.8	6,154.8	9,000	4,100
64	9	7,678.3	10,643.3	14,000	9,000
64	10	5,590.5	7,909.7	10,000	6,000
64	11	8,750.6	10,480.0	15,000	7,400
64	12	9,805.0	10,208.3	16,000	11,000
65	1	7,131.4	9,606.5	16,000	8,800
65	2	5,454.1	7,407.1	11,000	6,900
65	3	5,470.3	7,374.2	8,800	5,800
65	4	4,304.0	6,436.7	10,000	3,600
65	5	1,813.7	2,493.5	3,600	1,800
65	6	1,454.8	2,110.0	3,000	1,400
65	7	1,895.5	1,977.4	3,100	1,100
65	8	3,519.1	3,854.8	6,900	3,000
65	9	6,065.9	5,990.0	6,900	5,100
65	10	5,356.0	5,590.0	7,900	4,100
65	11	5,236.3	5,446.7	9,600	4,100
65	12	5,389.6	4,322.6	9,900	4,400
66	1	5,481.3	5,512.9	8,300	4,500
66	2	4,017.6	4,400.0	8,600	3,400
66	3	4,410.9	4,896.8	7,100	3,700
66	4	4,880.3	4,860.0	5,800	3,800
66	5	1,989.7	2,470.8	3,800	2,000
66	6	1,123.4	1,354.0	1,800	760
66	7	366.7	483.9	1,700	70
66	8	676.6	649.7	4,400	70
66	9	4,481.7	4,386.7	5,200	4,300
66	10	4,690.9	4,280.6	4,800	3,400
66	11	4,603.3	4,380.0	8,300	3,200
66	12	4,907.2	4,361.3	8,000	4,100

TABLE A.38. Calculated and Measured Chromium-51 Concentrations in the Pasco Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	12,620.2		11531	6800
64	2	9,528.4		8800	7382
64	3	9,668.2		12680	9267
64	4	6,758.3		15238	8000
64	5	3,770.6	4174.2	6800	2472
64	6	1,746.0	1336.7	2100	1200
64	7	1,376.0	1877.4	2591	1000
64	8	3,837.4	4500.0	6100	2400
64	9	7,427.0	8253.3	11050	5167
64	10	5,396.8	6106.5	16620	4200
64	11	8,399.6	8553.3	10000	5800
64	12	9,162.5	8580.6	11000	9000
65	1	6,622.6	7132.3	9100	5005
65	2	4,949.2	5614.3	9290	4200
65	3	5,050.7	5487.1	6564	3547
65	4	4,087.4	5080.0	6900	4000
65	5	1,769.0	1689.4	2900	1200
65	6	1,430.8	1342.7	1973	790
65	7	1,873.9	1280.6	2563	900
65	8	3,448.5	2745.2	3600	2100
65	9	5,864.3	4980.0	6100	4000
65	10	5,116.9	4925.8	8260	3600
65	11	5,036.4	4870.0	5550	3600
65	12	5,209.0	3725.8	5171	3900
66	1	5,270.5		5B88	4371
66	2	3,895.9		3640	3480
66	3	4,210.1		6191	5169
66	4	4,601.8		6136	3220
66	5	1,950.8		2406	1249
66	6	1,112.1		1406	940
66	7	362.4		959	3.2
66	8	663.2		4272	3.6
66	9	4,334.5		5122	4740
66	10	4,487.3			
66	11	4,415.6			
66	12	4,740.7			

TABLE A.39. Calculated and Measured Chromium-51 Concentrations in the Finley Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	8062.1			
64	2	6732.5			
64	3	6334.2			
64	4	3322.2			
64	5	2196.2			
64	6	1202.0			
64	7	1145.9			
64	8	3153.1			
64	9	5372.9			
64	10	4120.7			
64	11	5901.3			
64	12	4812.6			
65	1	3674.5			
65	2	2626.3			
65	3	2886.0			
65	4	2064.1			
65	5	1080.4			
65	6	958.0			
65	7	1444.5			
65	8	2702.5			
65	9	4147.4			
65	10	3339.1			
65	11	3460.5			
65	12	3611.7			
66	1	3372.0			
66	2	2740.3			
66	3	2747.6			
66	4	2545.4			
66	5	1369.7			
66	6	904.5			
66	7	321.5			
66	8	560.8			
66	9	3376.6			
66	10	3327.8			
66	11	3148.7			
66	12	3359.9			

TABLE A.40. Calculated and Measured Chromium-51 Concentrations in the McNary Reach (pCi/L)

Year	Month	Calculated Value	Average of Measured Values	Measured Values High Value	Measured Values Low Value
64	1	7384.6			
64	2	6218.5	5793.1	6000	5300
64	3	5831.8	6025.8	6900	5500
64	4	3098.1	3993.3	5500	3000
64	5	2124.4	1893.9	3600	650
64	6	1183.0	890.3	950	250
64	7	1116.6	1234.2	2100	980
64	8	2988.0	3190.3	4100	2100
64	9	4992.2	5040.0	6000	3700
64	10	3848.7	4003.2	5800	2900
64	11	5468.4	4293.3	5000	4200
64	12	4449.9	5119.4	6400	2800
65	1	3418.0	3206.5	3400	2600
65	2	2488.2	2214.3	2600	1700
65	3	2692.7	2722.6	4000	1800
65	4	1974.4	2343.3	3300	1000
65	5	1054.5	772.6	900	360
65	6	940.3	451.0	720	100
65	7	1399.2	930.0	1757	460
65	8	2563.8	2056.0	2700	1700
65	9	3863.7	3203.3	3611	2700
65	10	3097.8	2900.0	3900	2000
65	11	3213.0	4516.7	3300	2300
65	12	3355.6	5106.5	4200	66
66	1	3122.2	2929.0	3300	2500
66	2	2548.2	2553.6	3400	1800
66	3	2547.0	2467.7	3008	2100
66	4	2388.3	2003.3	2900	1800
66	5	1320.6	1377.4	1900	648
66	6	880.4	896.3	1219	540
66	7	309.8	387.7	1100	10
66	8	526.6	79.2	2877	14
66	9	3126.9	2410.7	3311	1900
66	10	3076.7	2300.0	2800	1900
66	11	2909.7	2440.0	3000	1800
66	12	3108.6	2374.2	3000	1800

APPENDIX B

MEASURED SEDIMENT CONCENTRATIONS

TABLE B.1. Surficial Bed Sediment (0 - 3 in.) Radionuclide Concentrations for the Ringold Reach (pCi/G)

Radionuclide	Mean Value	High Value	Low Value
Chromium-51	5946	5946	5946
Zinc-65	6081	6081	6081
Manganese-54	486	486	486

Note: Actual sample was taken near Richland during 1964. Ringold Reach is assumed to be similar. Only one set of measurements was reported, therefore, mean, high and low are identical.

TABLE B.2. Surficial Bed Sediment (0 - 3 in.) Radionuclide Concentrations for the Pasco Reach (pCi/G)

Radionuclide	Mean Value	High Value	Low Value
Chromium-51	1954	7300	260
Zinc-65	1385	3700	540
Manganese-54	N/A	N/A	N/A

Note: Data were collected periodically at Pasco Highway bridge between August 1962 and March 1965. The mean value above is the mean of all 1964 samples. High and low are for 1964 data only. Sixteen samples were available.

TABLE B.3. Surficial Bed Sediment (0 - 3 in.) Radionuclide Concentrations for the Finley Reach (pCi/G)

Radionuclide	Mean Value	High Value	Low Value
Chromium-51	562	1510	82
Zinc-65	229	741	31
Manganese-54	11	28	2

Note: Data were collected in September 1965.

TABLE B.4. Surficial Bed Sediment (0 - 3 in.) Radionuclide Concentrations for the McNary Reach (pCi/G)

Radionuclide	Mean Value	High Value	Low Value
Chromium-51	580	1640	89
Zinc-65	470	1600	87
Manganese-54	14	45	2

Note: Data were collected in September 1965.

APPENDIX C

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

Document Number PNL-7248 HEDR

Document Title Estimates of Columbia River Radionuclide Concentrations: Data for Phase I Dose Calculations

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
1.	J. Stohr (JS)	Page 3, Table 1	My 1984 references list the half-lives of Np-239 and Zn-65 as 2.35 and 244 days, respectively. Are these correct or were more recent sources used?	A reference has been added for the source of the half-lives given in Table 1.
2.	JS		Graphic comparisons between the measured and calculated values for river concentrations over the 1964-1966 time period would be interesting and possibly useful, especially if done in a manner similar to that presented for iodine-131 on vegetation.	NA - These comparisons will be done in a future report.
3.	MA Robkin (MAR)	Page 4	In the discussion for Equation (1), the dimensions are badly mixed (for example, pCi/L versus Ci/mo, and months versus days).	The units have been changed.
4.	MAR		Add a brief discussion of the mixing length in the river in the reach from Vernita to Richland and a similar discussion on the thermal equilibration length in the same reach.	NA - This will be discussed in detail in a future report.
5.	G.G. Caldwell (GGC)	Page v, para. 2	Have the effects of fuel leaks and variable intake and exhaust cooling water treatments been considered?	NA - No, not directly. Only to the extent that these sources are included in the overall radionuclide flow rate measurement.

NA - No action.

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

Document Number PNL-7248 HEDR Document Title Estimates of Columbia River Radionuclide Concentrations: Data for Phase I Dose Calculations

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
6.	GGC	Page 11, sentence about mass flow rates	How valid is this assumption? Is it likely to increase or decrease the ultimate estimated dose? Increase uncertainty?	NA - An uncertainty analysis of the river model will be addressed in a future report.
7.	GGC	Table 4	1) What will the effects of leaks and water treatment during 1944-1963 be? 2) Do we have data for number of leaks by reactor by year?	NA - 1) Beyond the Phase I scope. 2) Data may be available. Fuel failures are a subject of future study.
8.	GGC	Appendix A	1) Why are most calculated values higher than measured values? 2) Will measured values be used when available and calculations used when needed?	NA - 1) Most computed values are not higher than measurements. 2) This report does not address which values were used in dose calculations. Dose estimate report is identified in PNL-7411 HEDR, "Draft Columbia River Pathway Report."
9.	GGC	Pages A.21-A.35	Why are there so few calculated values? I understand from the text the dearth of measurements?	NA - See pages 3 and 4 of text for explanation.
10.	P. Klingeman (PK)		An extensive literature review and the development of a conceptual model are being undertaken by the subtask group. This work should be incorporated in the report or in a companion report.	NA - Will be addressed in a future report.

NA - No action.

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

Document Number PNL-7248 HEDR

Document Title Estimates of Columbia River Radionuclide Concentrations: Data for Phase I Dose Calculations

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
11.	PK		Elaborate on the radionuclides that were introduced to and transported in the river, and the times, locations, and methodologies used for sampling the river water, sediment and biota.	NA - Will be addressed in a future report.
12.	PK		Complete and include in the Phase I report the conceptual model for the river pathway for the Hanford reach of the Columbia River.	NA - Will be addressed in a future report.
13.	PK	Pages 4-6	The calculation of radionuclide concentrations needs to be described in more detail. The rationale for selecting the given approach as the first approximation should be justified.	A short statement was added.
14.	PK	Page 1, para. 2, line 2	Typo--developing models.	Corrected.
15.	PK	Page 3, Table 1	Give the rationale for the particular sequence of radionuclides listed (it is not alphabetical or in any other initially obvious sequence).	List is now in alphabetical order.
16.	PK	Page 4	Reference to appendix tables: Why don't some tables have complete sets of values (e.g., Tables A.21 to A.35)?	Missing values indicate lack of data. Statement added on p. 4.

NA - No action.

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

Document Number PNL-7248 HEDR Document Title Estimates of Columbia River Radionuclide Concentrations: Data for Phase I Dose Calculations

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
17.	PK	Appendix tables	A column should be added that gives the number of discrete samples collected on which the measured average, high, and low values are based.	NA - Not available at the time of Phase I report, but will be included in subsequent reports.
18.	PK	Appendix tables	Table A.1 and others have identical numerical values for the high value and low value. If these represent single samples, then "high" and "low" are misleading.	NA - True, but we were limited by the data that were available.
19.	PK	Page 4, eq. 1	The conversion factor is missing.	Corrected by making units consistent.
20.	PK	Page 4	Terms for Equation 1: Dimensions are missing for Tj.	Added.
21.	PK	Page 4	Make clear that your "effluent mass flow rate" is not the conventional "mass flow rate" used in river hydraulics (i.e., slugs/sec or kilograms/sec)	We believe it is clear. No change. The units used define what the terms mean. It is standard nomenclature for PNL work.
22.	PK	Page 5	Assumptions/limitations: Since assumptions are not the same as limitations, these should be differentiated. Maybe the limitations should be shown in parentheses.	For this report, we believe that a single category is sufficient.

NA - No action.

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

Document Number PNL-7248 HEDR

Document Title Estimates of Columbia River Radionuclide Concentrations: Data for Phase I Dose Calculations

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
23.	J. E. Till (JET)		The report needs a conclusion.	NA - The purpose of the report was to provide concentration estimates to dose modelers. Any conclusion as to the accuracy, etc., of the calculation method will be addressed in a future report.
24.	JET		Can we add more about the "reasonableness" of the assumptions? Surely the Columbia River has been modeled extensively by many groups.	NA - "Reasonableness" will be discussed in a future report. No, the Columbia River has not been extensively modeled.
25.	JET	Page 1, para. 4	I would like to see more results in the QA section of the report if possible. For example, if we are having the data entry verified, how many errors did we find? What was the size of the QA sample?	NA - See PNL-7428 HEDR, "QA Audit Report of the HEDR Project - Data Traceability, A-90-15."
26.	B. Shleien (BS)		Report contains no conclusions as to the comparison between measured values and calculated results.	NA - See response to #23. This will be done in a future report.
27.	BS		How were different radionuclides, locations, dates, river flow, etc. compared?	NA - They were not compared in this report.
28.	BS		Which set of data will be used for Phase I? Factors of 2 or so in either direction appear to exist between calculated and measured information.	NA - Data used are explained in PNL-7411 HEDR, "Draft Columbia River Pathway Report."

NA - No action.

SUMMARY OF TSP COMMENTS AND BATTELLE RESPONSES

Document Number PNL-7248 HEDR Document Title Estimates of Columbia River Radionuclide Concentrations: Data for Phase I Dose Calculations

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
29.	BS		Iodine-131 should be considered in calculations of dose from the Columbia River in Phase I for the period 1944-1947.	NA - Iodine-131 will be used for dose estimates in future work.
30.	M.L. Blazek (MLB)		Iodine-131 should be included in Columbia River water dose calculations.	NA - Iodone-131 will be used for dose estimates in future work.
31.	MLB		What was the correlation between measured and calculated values?	NA - will be addressed in a future report.
32.	A. Slickpoo		I would be interested in seeing the final determination about "Estimates of Columbia River Radionuclide Concentrations." Would iodine be the only source?	NA - Final source terms and concentrations will be provided in future documents.

NA - No action.

DISTRIBUTION

No. of Copies

OFFSITE

18 Technical Steering Panel

D. S. Barth
University of Nevada
4505 Maryland Parkway
Las Vegas, NV 89154

W. A. Bishop
2503 Wedgewood Court SE
Olympia, WA 98501

M. L. Blazek
Oregon Department of Energy
625 Marion Street N.E.
Salem, OR 97310

G. G. Caldwell
Director
Tulsa City-County Health Dept.
4616 East 15th Street
Tulsa, OK 74112

S. N. Davis
Dept. of Hydrology & Water Resources
Bldg. 11
University of Arizona
Tucson, AZ 85721

N. J. Germond
224 Iron Mountain Blvd.
Lake Ozwego, OR 97034

P. C. Klingeman
Civil Engineering Dept.
Oregon State University
Corvallis, OR 97331-2302

No. of Copies

K. J. Kopecky
Fred Hutchinson Cancer Research Center
1124 Columbia Street
Seattle, WA 98104

R. L. Morrill
Dept. of Geography
DP-10
University of Washington
Seattle, WA 98195

A. H. Murphy
c/o Climate Analyses Center
National Weather Service, NOAA
W/NMC51, WWB, Room 604
Washington, DC 20233

V. Nguyen
EWA, Inc.
133 1st Ave. N.
Minneapolis, MN 55401

D. W. Price
Agricultural Economics
Hulbert Hall Room 211
Washington State University
Pullman, WA 99164-6210

M. A. Robkin
Radiological Sciences SB-75
University of Washington
Seattle, WA 98195

G. S. Roessler
Rt. 1, Box 139H
Elysian, MN 56028

No. of
Copies

B. Shleien
2421 Homestead Drive
Silver Springs, MD 20902

A. P. Slickpoo, Sr.
P. O. Box 331
809 Nez Perce Lane
Kamiah, ID 83536

J. E. Till
Rt. 2 Box 122
Neeses, SC 29107

D. E. Walker, Jr.
c/o P. Arroyo
2041 Walnut St.
Boulder, CO 80302

2 DOE Office of Scientific and Technical Information
Technical Information Center
P.O. Box 62
Oak Ridge, TN 37830

18 K. CharLee
Office of Nuclear Waste Mgmt.
Department of Ecology
99 South Sound Center
Mail Stop PV-11
Olympia, WA 98504

J. Thomas, HEAL
325 S. Oak St.
Spokane, WA 99204

No. of
Copies

ONSITE

2 DOE Richland Operations

R. F. Brich, SED	A5-55
M. W. Tiernan, SED	A5-55

36 Pacific Northwest Laboratory

J. M. Daer (10)	K6-89
W. A. Glass (6)	K4-13
S. P. Gydesen	P8-55
A. H. McMakin	K6-86
B. A. Napier	K3-54
M. C. Richmond (5)	SEQUIM
W. L. Templeton	K1-30
W. H. Walters	K6-77
S. B. Yabusaki	K6-77
Public Reading Room (5)	A1-65
Publishing Coordination	K1-11
Records Center	K3-70
Technical Library (2)	P8-55